Mancos Fractured Shale Play

(USGS 2208)

General Characteristics

The Mancos Fractured Shale Play (Fig. SU-51) is a confirmed, unconventional, continuous-type play (Gautier et al., 1996). It is dependent on extensive fracturing in the organic-rich marine Mancos Shale. Most developed fields in the play are associated with anticlinal and monoclinal structures around the eastern, northern, and western margins of the San Juan Basin (Fig. SU-52).

Reservoirs: Reservoirs comprise fractured shale and interbedded coarser clastic intervals at approximately the Tocito Lentil stratigraphic level.

Source rocks: The Mancos Shale contains 1-3 weight percent organic carbon and produces a sweet, low-sulfur, paraffin-base oil that ranges from 33° to 43° API gravity.

Timing: The upper Mancos Shale of the central part of the San Juan Basin entered the thermal zone of oil generation in the late Eocene and of gas generation in the Oligocene.

Traps: Combination traps predominate. Traps formed by fracturing of shale and by interbedded coarser clastics on structures are common.

Exploration status and resource potential: Most of the larger discoveries, such as Verde and Puerto Chiquito, were made prior to 1970, but directional drilling along the flanks of some of the poorly explored structures could result in renewed interest in this play.

Characteristics of Mancos Fractured Shale Play

The Mancos Fractured Shale play produces oil from fractures in the Niobrara-Carlile age clastic sediments (Fig. SU-53) which represent the first regressive wedge in the San Juan Basin (Gorhman et al.,1978; DuChene, 1989). These sediments have little or no effective porosity and permeability except that associated with fractures. The units of interest to oil exploration are the basal Niobrara (lower Tocito Sandstone), Niobrara-Carlile unconformity (upper Carlile Shale-Tocito Sandstone contact), and Carlile Shale/siltstone interval above the Juana Lopez (Fig. S-53). The Niobrara-Carlile stage is laterally consistent with respect to siltstone content, cement content, and other observable stratigraphic phenomenon.

The Hogback Monocline (Fig. SU-52) is the structural feature associated with the fractures in the Mancos Shale. It is located in the northwest flank of the San Juan Basin, southwest part of the Southern Ute Indian Reservation. It has a dip as great as 60° and has up to 8,000 feet of structural relief. Fractures are mostly associated with areas of maximum flexure and where anticlines and synclines intersect the monocline. The fractures are best developed parallel to the trend of the fold. Fracture apertures range from 1 3/4 inches to hairline cracks.

Oil reservoirs associated with the Mancos Fractured Shale Play depend on secondary porosity and permeability provided by the fractures. The reservoirs are lithologically controlled only to the extent that brittle competent interbeds capable of fracturing are present. The fractures have greater lateral, than vertical continuity. The basic tools used in exploration for fracture permeability are structure contour maps and lithofacies maps showing brittle interbeds in dominantly shaly sequences.

Trap types are structural/stratigraphic - fracture traps. The reservoirs are primarily driven by gravity drainage.

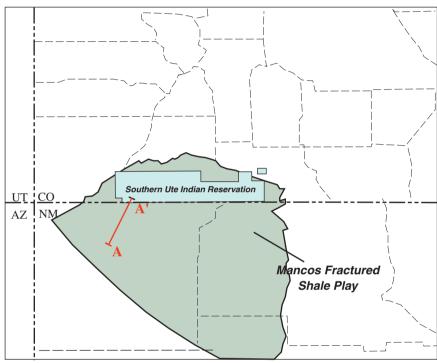


Figure SU-51 Location of the Mancos Fractured Shale Play (modified after Gautier et al., 1996).

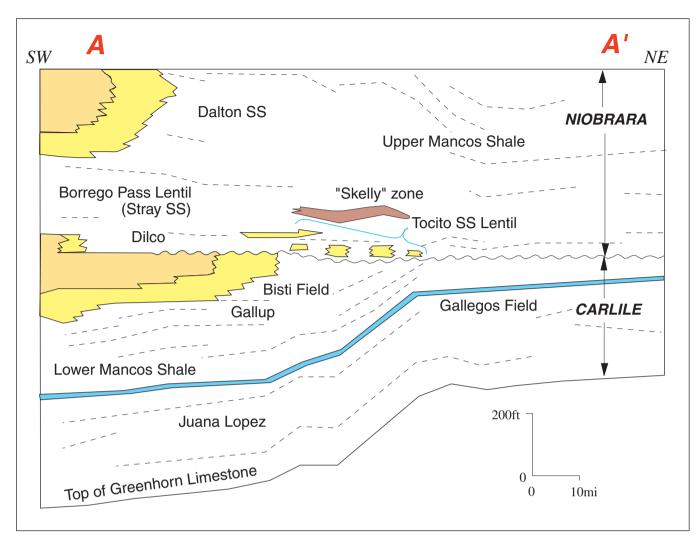


Figure SU-53 Subsurface stratigraphic cross section across the central San Juan Basin. Dashed lines are time marker bentonites or calcareous silty zones. Approximate location of section is labeled in Figure SU-51 (modified after Molenaar, 1973 and Tillman, 1985).

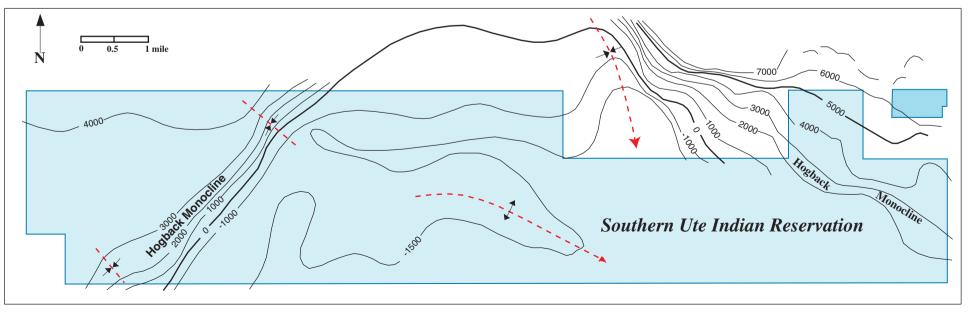


Figure SU-52 Structure contour map of the Dakota Sandstone showing the Hogback Monocline and associated anticlines and synclines (modified after Anderson, 1995).

Analog Fields in and near Reservation

(*) denotes that field lies within the reservation boundaries

La Plata Gallup

(Figs. SU-54 & SU-55)

Location of discovery well: SE, SW, sec 5, T31N, R13W (1959)

Producing formation: Cretaceous Mancos Shale Stratigraphic, Fractured Shale Type of trap:

Number of producing wells: 4 (1978) 241 BOD Initial production:

Cumulative Production: 635,144 BO and 539, 607 MCGG (1994) Oil characteristics: Sweet, yellow-green, 38° API gravity Type of drive: Combination gravity drainage and solution gas

Average net pay: uncertain, probably less than 30 feet Porosity: uncertain, probably on the order of 1%

Unknown Permeability:

Verde Gallup

(Fig SU-54)

SE, SE, sec 14, T31N R15W (1955) Location of discovery well: Producing formation: Fractured interval in Cretaceous "Gallup"

sandstone (basal Niobrara age rocks)

Fractured shale, structural Type of trap:

Number of producing wells: 27 (1978) 180 BOD Initial production:

Cumulative Production: 7,963,004 BO and 174,956 MCFG (1994)

Oil characteristics: 38-42° API gravity Gravity drainage Type of drive:

Average net pay: Variable Porosity: Fracture Unlimited Permeability:

Chromo (poor historical data)

Ref: Fassett, 1983, 1978; Wells and Lay, 1996

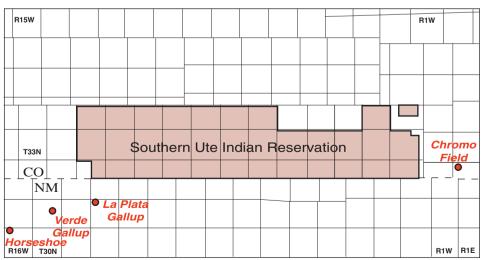


Figure SU-54 Location of oil field discovery wells for fields producing from the Mancos Fractured Shale Play.

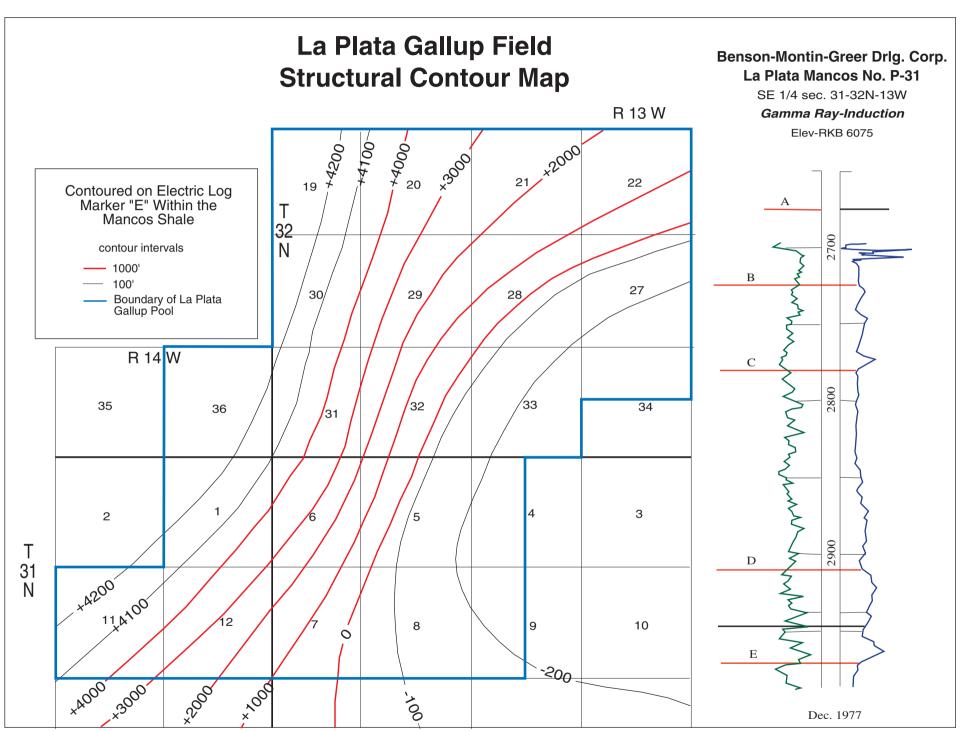


Figure SU-55 Structure contour map and type log for the La Plata Gallup field. Structure contour lines are drawn on the "E" marker which is the top of the Niobrara Stage, which generally produces highest electrical resistivities in the Mancos Shale. Contour interval is 100 feet. (modified after Greer, 1978).

Central Basin Mesaverde Gas Play

(USGS 2209)

General Characteristics

The unconventional continuous-type Central Basin Mesaverde Gas Play is in sandstone buildups associated with stratigraphic rises in the Upper Cretaceous Point Lookout and Cliff House Sandstones (Gautier et al, 1996). The major gas-producing interval in the San Juan Basin, the Upper Cretaceous Mesaverde Group comprises the regressive marine Point Lookout Sandstone, the nonmarine Menefee Formation, and the transgressive marine Cliff House Sandstone. Total thickness of the interval ranges from about 500 to 2,500 ft, of which 20-50 percent is sandstone. The Mesaverde interval is enclosed by marine shale; the Mancos Shale is beneath the interval and the Lewis Shale above.

Reservoirs: Principal gas reservoirs productive in the Mesaverde interval are the Point Lookout and Cliff House marine sandstones. Smaller amounts of dry, non-associated gas are produced from thin, lenticular channel sandstone reservoirs and thin coal beds of the Menefee. Much of this play is designated as tight, and reservoir quality depends mostly on the degree of fracturing. Together, the Blanco Mesaverde and Ignacio Blanco fields account for almost half of the total non-associated gas and condensate production from the San Juan Basin. Within these two fields porosity averages about 10 percent and permeability less than 2 md; total pay thickness is 20-200 ft. Smaller Mesaverde fields have porosities ranging from 14 to 28 percent and permeabilities from 2 to 400 md, with 6-25 ft of pay thickness.

Source rocks: The carbon composition (C1/C1-5) of 0.99-0.79 and isotopic carbon (d13C1) range of -33.4 to -46.7 per mil of the nonassociated gas suggest a mixture of source rocks including coal and carbonaceous shale in the Menefee Formation (Rice, 1988). Timing and migration: In the central part of the basin, the Mancos Shale entered the thermal zone of oil generation in the Eocene and of gas generation in the Oligocene. The Menefee Formation also entered the gas generation zone in the Oligocene. Because basin configuration was similar to that of today, updip migration would have been toward the south. Migration was impeded by hydrodynamic pressures directed toward the central basin, as well as by the deposition of authigenic swelling clays due to dewatering of Menefee

Traps: Trapping mechanisms for the largest fields in the central part of the San Juan Basin are not well understood. In both of these fields, the Blanco Mesaverde and Ignacio Blanco, hydrodynamic forces are believed to contain gas in structurally lower parts of the basin, but other factors such as cementation and swelling clays may also play a role. Production depths are most commonly from 4,000 to 5,300 ft. Updip pinchouts of marine sandstone into finer grained paludal or marine sediments account for almost all of the stratigraphic traps with a shale or coal seal.

Exploration status and resource potential: The Blanco Mesaverde field discovery well was completed in 1927, and the Ignacio Blanco Mesaverde field discovery well was completed in 1952. Areally, these two adjacent fields cover more than 1,000,000 acres, encompass much of the central part of the San Juan Basin, and have produced almost 7,000 BCFG and more than 30 MMB of condensate, approximately half of their estimated total recovery. Most of the recent gas discoveries range in areal size from 2,000 to 10,000 acres and have estimated total recoveries of from 10 to 35 BCFG.

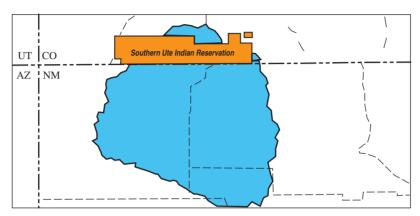
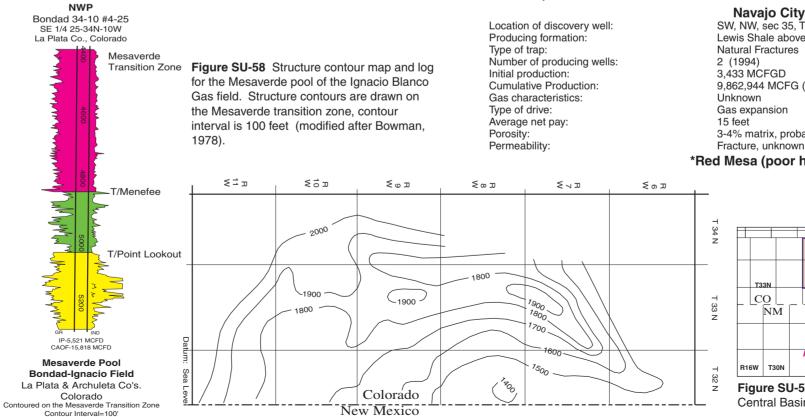


Figure SU-56. Location of the Central Basin Mesaverde Gas Play (modified after Gautier et al., 1996).



Analog Fields in and near Reservation

(*) denotes field lies within the reservation boundaries)

Location of discovery well:

Number of producing wells:

Producing formation:

Cumulative Production

Gas characteristics:

Producing formation:

Type of trap:

Type of drive:

Permeability:

Type of trap:

Type of drive:

Permeability:

Type of trap:

Type of drive:

Porosity Permeability:

Porosity:

Initial production:

Average net pay:

Gas characteristics:

Location of discovery well:

Number of producing wells:

Cumulative Production:

Producing formation

Initial production:

Average net pay:

Gas characteristics:

Porosity:

Average net pay:

Initial production:

* Ignacio Blanco (see Fig SU-58) SE, SW, sec 15, T32N, R11W (1952) Cretaceous Mesaverde Stratigraphic, basinal hydrodynamic trapping 825 (1992) 1,710 MCFGD 625,860,995 MCFG, 257,988 B Condensate (1992) BTU 970-1040 range Gas expansion, dry gas reservoir 20 - 150 feet 9.1% ave.

0.02-0.5 mD intergranular, enhanced by natural fractures

Animas Chacra

Location of discovery well: NW. NW. sec 6, T31N, R10W (1975) Cretaceous Chacra: sandstone (tongue of La Ventana Member, Cliff House ss) 1 (1994) Number of producing wells: 3.300 MCFG 8.086.233 MCFG and 1.988 B Condensate Cumulative Production: Unknown Gas expansion 42 feet

4-6%

Unknown

Flora Vista Mesaverde

SW, SW, sec 22, T30N, R12W (1961) Cretaceous Cliff House Sandstone Stratigraphic 9 (19994) 5.988 MCFGD 20,267,279 MCFG and 96,159 B Condensate BTU 1,252 Solution Gas 18.5 feet 14-17% 2-3 md

Navajo City Chacra

SW, NW, sec 35, T30N, R8W (1974) Lewis Shale above "Chacra" tongue of Cliff House Sandstone Natural Fractures 2 (1994) 3,433 MCFGD 9,862,944 MCFG (1994) Unknown Gas expansion 15 feet 3-4% matrix, probably fracture

*Red Mesa (poor historical data)



Figure SU-57. Location of discovery wells for fields producing from Central Basin Mesaverde Gas Play.

Pictured Cliffs Gas Play

(USGS 2211)

General Characteristics

The Pictured Cliffs unconventional, continuous-type play is defined primarily by gas production from stratigraphic traps in sandstone reservoirs enclosed in shale or coal at the top of the Upper Cretaceous Pictured Cliffs Sandstone and is confined to the central part of the basin (Gautier et al., 1996). Thicker shoreline sandstones produced by stillstands, or brief reversals in the regression of the Cretaceous sea to the northeast, have been the most productive. The Pictured Cliffs is the uppermost regressive marine sandstone in the San Juan Basin. It ranges in thickness from 0 to 400 ft and is conformable with both the underlying marine Lewis Shale and the overlying nonmarine Fruitland Formation.

Reservoirs: Reservoir quality is determined to a large extent by the abundance of authigenic clay. Cementing material averages 60 percent calcite, 30 percent clay, and 10 percent silica. Average porosity is about 15 percent and permeability averages 5.5 md, although many field reservoirs have permeabilities of less than 1 md. Pay thicknesses range from 5 to 150 ft but typically are less than 40 ft. Reservoir quality improves southward from the deepest parts of the basin due to secondary diagenetic effects.

Source rocks: The source of gas was probably marine shale of the underlying Lewis Shale and nonmarine shale of the Fruitland Formation. The gas is nonassociated and contains very little condensate (0.006 gal/MCFG). It has a carbon composition (C1/C1-5) of 0.85-0.95 and an isotopic carbon (d13C1) range of -43.5 to -38.5 per mil (Rice, 1988).

Timing and migration: Gas generation was probably at a maximum during the late Oligocene and the Miocene. Up-dip gas migration was predominantly toward the southwest because the basin configuration was similar to that of today.

Traps: Stratigraphic traps resulting from landward pinchout of nearshore and foreshore marine sandstone bodies into finer grained silty, shaly, and coaly facies of the Fruitland Formation (especially in the areas of stratigraphic rises) contain most of the hydrocarbons. Seals are formed by finer grained back-beach and paludal sediments into which marine sandstones intertongue throughout most of the central part of the basin. The Pictured Cliffs Sandstone is sealed off from other underlying Upper Cretaceous reservoirs by the Lewis Shale. The Pictured Cliffs crops out around the perimeter of the central part of the San Juan Basin and is present at depths of as much as 4,300 ft. Most production has been from depths of 1,000-3,000 ft.

Exploration status and resource potential: Gas was discovered in the play in 1927 at the Blanco and Fulcher Kutz fields of northwest New Mexico. Most Pictured Cliffs fields were discovered before 1954, and only nine relatively small fields have come into production since then. Discoveries since 1954 average about 11 BCFG estimated ultimate recovery. A large quantity of gas is held in tight sandstone reservoirs north of the currently producing areas. Stratigraphic

traps and excellent source rocks are present in the deeper parts of the basin, but low permeabilities due to authigenic illite-smectite clay have thus far limited production.

Characteristics of the Pictured Cliffs Gas Play on the Southern Ute Indian Reservation

Numerous studies have focused on the Pictured Cliffs Sandstone in the Southern Ute Indian Reservation in the past ten years. For this reason, the following should be considered an extremely brief over-

The Pictured Cliffs Sandstone represents a littoral deposit in a wave dominated system during the final northeasterly regression of the Cretaceous sea. The Lewis Shale is stratigraphically below and intertongues with the Pictured Cliffs (Fig. SU-61). In recent years, Pictured Cliffs gas development has shifted from a depleted structural accumulation to a stratigraphically trapped accumulation (Harr, 1988, and Hoppe, 1992). Two interpretations for high gas production exist in the literature. The first is that gas production is controlled by local sandstone lenticularity and permeability barriers (shales) developed along the shore-side slope of coastal barriers. Higher yield wells are attributed to individual thicker sandstone lenses which are least shalev. The second interpretation is that the Pictured Cliffs is characterized as a low-permeability, gas saturated reservoir with production dependent on fractures. Fractures play a crucial role in production. The highest producing wells in the Pictured Cliffs show communication between them, which is explained by fractures. For this reason, fracture identification is important in identifying new reservoirs. Landsat imagery (Fig. SU-62) and multi-component 3-D seismic are being used to interpret fracture orientations and frequencies in the subsurface.

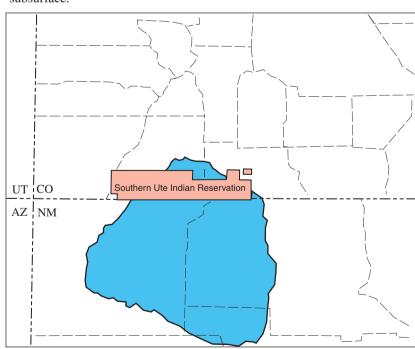


Figure SU-59. Location of the Pictured Cliffs Gas Play (modified after Gautier et al., 1996)

Figure SU-60. Structure contour map of the Pictured Cliffs Sandstone and major structural features (modified after Kelso and Wicks. 1988).

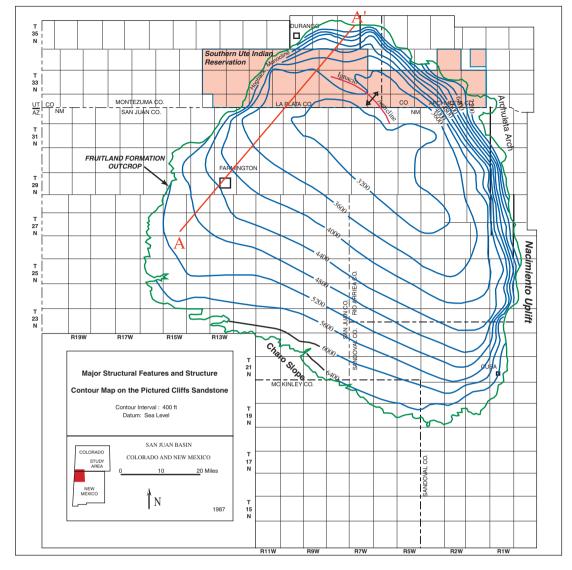
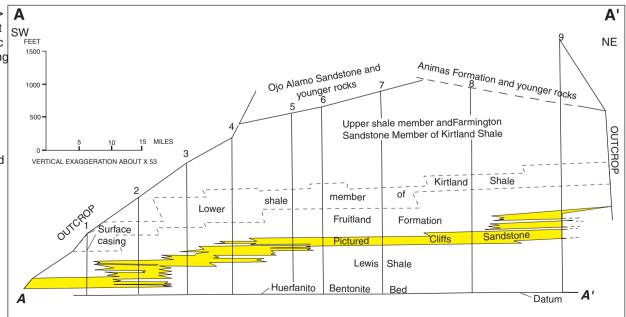


Figure SU-61. --> **A** Southwest-northeast SW trending stratigraphic cross section showing the northeast stratigraphic rise of the Pictured Cliffs Sandstone and associated rocks. Section is located in Fig. SU-60 (modified after Fassett, 1988).



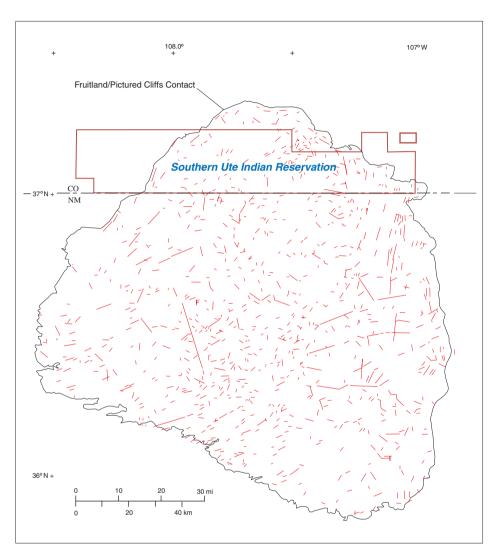


Figure SU-62. Landsat lineaments in the San Juan Basin (modified after Baumgardner, 1994).

Analog Fields within and near Reservation

(*) denotes field lies within the reservation boundaries)

*Ignacio Blanco (see Figs. 63 and 64)

NE ¼, NW ¼, sec 7, T33N, R7W (1951) Location of discovery well: Cretaceous Pictured Cliffs Sandstone ·Producing formation:

Structural / Stratigraphic ·Type of trap:

·Number of producing wells: 115 (1986) ·Initial Production: 2,200 MCFGD

26,750,352 MCFG (1986) ·Cumulative Production:

·Gas characteristics: 990 BTU ·Type of drive: Solution gas

16-205 feet, 70 feet average ·Average net pay:

·Porosity: 4.4%

·Permeability: 0 - 1500 mD

Albino Pictured Cliffs

·Location of discovery well: SE ¼, SW ¼, sec 26, T32N, R8W (1974) ·Producing formation: Cretaceous Pictured Cliffs Sandstone

·Type of trap: Stratigraphic ·Number of producing wells: 15 (1994) 556 MCFGD

·Initial Production: ·Cumulative Production: 7.260.895 MCFG (1994)

·Gas characteristics: 1,074 BTU ·Type of drive: Gas Expansion ·Average net pay: 40 feet average

·Porosity: 12% ·Permeability: NA

Aztec Pictured Cliffs

SE ¼, SW ¼, sec 10, T30N, R11W (1951) ·Location of discovery well: Cretaceous Pictured Cliffs Sandstone ·Producing formation:

·Type of trap: Stratigraphic 559 (1994) ·Number of producing wells: ·Initial Production: 180 MCFGD

·Cumulative Production: 340,024,535 MCFG (1994)

·Gas characteristics: 1,169 BTU

·Type of drive: Gas expansion with water encroachment

·Average net pay: 40 feet average

·Porosity: 15% 545 mD ·Permeability:

Twin Mounds Pictured Cliffs

SE ¼, SW ¼, sec 33, T30N, R14W (1951) Location of discovery well: Producing formation: Cretaceous Pictured Cliffs Sandstone Type of trap: Sratigraphic, up-dip gradation sand to shale

Number of producing wells: 7 (1994) Initial Production: 1,875 MCFGD

Cumulative Production: 2,288,169 MCFG (1986)

Gas characteristics: 1,153 BTU

Type of drive: Volumetric gas reservoir

Average net pay: 10 feet average 24%

Porosity: Permeability: 65 mD

(Fassett, 1983, 1978; Wells and Lay, 1996)

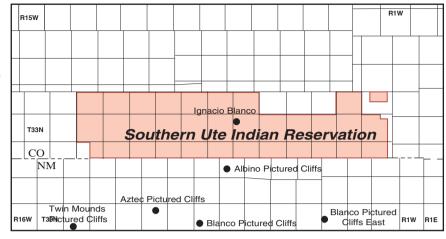


Figure SU-63. Location of discovery well for fields that produce from the Pictured Cliffs Gas Play in and near the Southern Ute Indian Reservation.

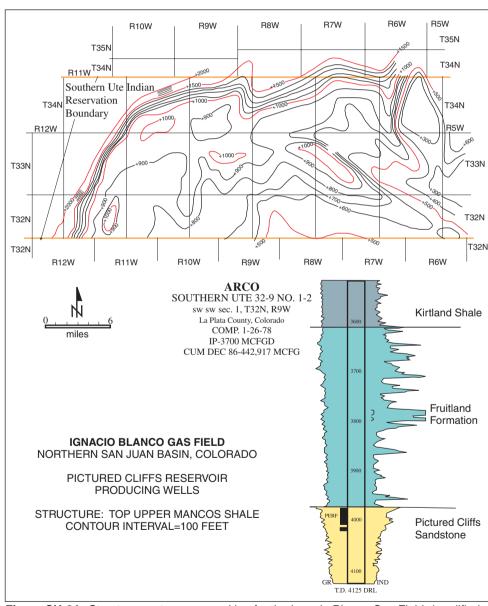


Figure SU-64. Structure contour map and log for the Ignacio Blanco Gas Field (modified after Harr, 1988).